The growth interval of garnet in the UHP eclogites from the Dabie orogen, China

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ABSTRACT

Zircon inclusions, extracted from garnet from an ultrahigh-pressure eclogite in the eastern part of the Dabie orogen, were investigated with high spatial resolution U-Pb geochronology. The unzoned zircon rims have garnet and omphacite inclusions and show weak cathodoluminescence, low-Th/U ratios (0.02–0.18), flat high rare-earth elements patterns, and an absence of Eu anomalies, which suggest metamorphic growth in the presence of garnet and in the absence of feldspar. Dispersed concordia U-Pb ages, ranging from 205.1 ± 3.3 to 255.3 ± 6.1 Ma, defined a weighted mean 206Pb/238U age of 223 ± 8 Ma (mean square of weighted deviation, MSWD = 38), which is significantly younger than the Lu-Hf garnet-whole rock age of 242.2 ± 2.6 Ma. The U-Pb age probability distribution indicates two age populations at ca. 241 and ca. 216 Ma. The zircon rims, with younger ages, are distinguished from those with older ages by the occurrence of garnet and omphacite inclusions. Well-preserved prograde major- and trace-element zoning in garnet and the significant contribution of older garnet cores in bulk isotopic digestion suggest that the Lu-Hf age mostly reflects an early phase of garnet growth likely at amphibolite facies conditions. The new Lu-Hf age combined with the U-Pb ages of the zircon inclusions in garnet suggest that garnet growth was sustained over a time interval of ~25 m.y.

Keywords: Garnet, Lu-Hf, U-Pb, zircon

INTRODUCTION

Determination of the duration and timing of mineral growth during metamorphism is fundamental to characterization of the evolution of metamorphic belts. Garnet-bearing rocks are the most suitable for this determination because the production and retention of compositional zoning in garnet over a wide range of metamorphic conditions can be used to constrain the P-T paths (e.g., Spear and Selverstone 1983; Kohn 2003). Linking geochronological records to garnet growth provides a direct constraint on the duration of the metamorphism (e.g., Christensen et al. 1989; Vance and O’Nions 1990; Duchêne et al. 1997; Ducea et al. 2003). Durations of garnet growth may possibly be inferred from zoned radiometric isotopes in single crystals of garnet (Christensen et al. 1989; Ducea et al. 2003), different chronologic systems [e.g., Lu-Hf vs. Sm-Nd (Lapen et al. 2003)], or data distributions on isochron diagrams (Kohn 2009). The first approach, which mostly uses the Sm-Nd and Rb-Sr systems, can accommodate small sample sizes [commonly less than 5 mg; e.g., Ducea et al. (2003); Harvey and Baxter (2009)]. The improved method reduces spatial resolution to ~1 mm. However, direct analysis of chronologic zoning for typical ultrahigh-pressure (UHP) metamorphic garnets that usually range from several hundred micrometers to about 2 mm is not practical. Sampling for the Lu-Hf isotope analysis requires ~250 mg of material (approximately a 4 × 4 × 4 mm³ cube of garnet). Therefore, retrieving the durations of garnet growth by sole radiometric isotopes in single crystals of typical UHP garnet (usually ~1 mm in diameter) is hardly feasible. For the second approach, comparison of Lu-Hf and Sm-Nd ages appears to be a promising method for determining the duration of prograde metamorphism (e.g., Scherer et al. 2000; Lapen et al. 2003; Cheng et al. 2008). Previous work has demonstrated that analyzing garnets may yield a Lu-Hf age reflecting a particular garnet growth stage in response to a particular metamorphic episode due to the complex parent/daughter element zonings and/or varied garnet growth mechanisms (e.g., Lapen et al. 2003; Skora et al. 2006; Cheng et al. 2009; Kylander-Clark et al. 2009; Wallis et al. 2009; Martin et al. 2010; Corrie et al. 2010). Systematic trace element zoning in garnet crystals must be, therefore, confirmed before durations can be fully quantified. Zircon has long been recognized as a promising geochronometer of the U-Pb decay system for retrieving the prograde and retrograde metamorphic evolution of the host rock (Gebauer 1996). Zircon may record multiple stages of growth and dissolution (Corfu et al. 2003; Harley et al. 2007). In particular, zircon inclusions in garnet are protected from daughter-product loss and may “freeze” the clock when included in garnet. In situ analysis of the zircon inclusions in garnet from core to rim is ideal for unraveling the garnet growth durations; however, the odds of exposing large-sized zircon inclusions in garnet (from core to rim) for ion probe analyses are extremely low during conventional thin-section preparation procedures.